ANX-PR/CL/001-01
GUÍA DE APRENDIZAJE

ASIGNATURA

93000943 - Laboratorio De Técnicas De Aprendizaje Automático

PLAN DE ESTUDIOS

09AT - Master Universitario En Teoria De La Señal Y Comunicaciones

CURSO ACADÉMICO Y SEMESTRE

2024/25 - Primer semestre

Índice

Guía de Aprendizaje

1. Datos descriptivos

1.1. Datos de la asignatura

Nombre de la asignatura	93000943 - Laboratorio de Técnicas de Aprendizaje Automático
No de créditos	4.5 ECTS
Carácter	Optativa
Curso	Primer curso
Semestre	Primer semestre
Período de impartición	Septiembre-Enero
Idioma de impartición	Inglés/Castellano
Titulación	09AT - Master Universitario en Teoria de la Señal y Comunicaciones
Centro responsable de la titulación	09 - Escuela Tecnica Superior De Ingenieros De Telecomunicacion
Curso académico	2024-25

2. Profesorado

2.1. Profesorado implicado en la docencia

Nombre	Despacho	Correo electrónico	Horario de tutorías *
Mateo Jose Camara Largo	C-301	mateo.camara@upm.es	Sin horario. Appointment arranged by email
Luis Alfonso Hernandez Gomez (Coordinador/a)	C-330	luisalfonso.hernandez@upm.es	Sin horario. Appointment arranged by email

Eduardo Lopez Gonzalo	C-330	eduardo.lopez@upm.es	Sin horario. Appointment arranged by email
Juan Ignacio Godino Llorente	C-312	ignacio.godino@upm.es	Sin horario. Appointment arranged by email

* Las horas de tutoría son orientativas y pueden sufrir modificaciones. Se deberá confirmar los horarios de tutorías con el profesorado.

3. Conocimientos previos recomendados

3.1. Asignaturas previas que se recomienda haber cursado

El plan de estudios Master Universitario en Teoria de la Señal y Comunicaciones no tiene definidas asignaturas previas recomendadas para esta asignatura.

3.2. Otros conocimientos previos recomendados para cursar la asignatura

- Previous exposure to a programming language, such as MATLAB, R or Python

- It is highly recommended to follow this course simultaneously with the subject Predictive and Descriptive Learning unless you have a theoretical background in Machine Learning and Deep Learning

4. Competencias y resultados de aprendizaje

4.1. Competencias

CB06 - Poseer y comprender conocimientos que aporten una base u oportunidad de ser originales en el desarrollo y/o aplicación de ideas, a menudo en un contexto de investigación

CB07 - Que los estudiantes sepan aplicar los conocimientos adquiridos y su capacidad de resolución de problemas en entornos nuevos o poco conocidos dentro de contextos más amplios (o multidisciplinares) relacionados con su área de estudio

CB08 - Que los estudiantes sean capaces de integrar conocimientos y enfrentarse a la complejidad de formular juicios a partir de una información que, siendo incompleta o limitada, incluya reflexiones sobre las

responsabilidades sociales y éticas vinculadas a la aplicación de sus conocimientos y juicios

CB09 - Que los estudiantes sepan comunicar sus conclusiones y los conocimientos y razones últimas que las sustentan a públicos especializados y no especializados de un modo claro y sin ambigüedades

CB10 - Que los estudiantes posean las habilidades de aprendizaje que les permitan continuar estudiando de un modo que habrá de ser en gran medida autodirigido o autónomo

CE01 - Analizar y aplicar técnicas para el diseño y desarrollo avanzado de equipos y sistemas, basándose en la teoría de la señal y las comunicaciones, en un entorno internacional

CE02 - Evaluar y sintetizar los resultados de un trabajo en equipo en proyectos relacionados con la teoría de la señal y las comunicaciones, en un entorno internacional.

CE03 - Valorar y contrastar la utilización de las diferentes técnicas disponibles para la resolución de problemas reales dentro del área de teoría de la señal y comunicaciones.

CT01 - Capacidad para comprender los contenidos de clases magistrales, conferencias y seminarios en lengua inglesa

CT03 - Capacidad para adoptar soluciones creativas que satisfagan adecuadamente las diferentes necesidades planteadas

CT04 - Capacidad para trabajar de forma efectiva como individuo, organizando y planificando su propio trabajo, de forma independiente o como miembro de un equipo

CT05 - Capacidad para gestionar la información, identificando las fuentes necesarias, los principales tipos de documentos técnicos y científicos, de una manera adecuada y eficiente

CT06 - Capacidad para emitir juicios sobre implicaciones económicas, administrativas, sociales, éticas y medioambientales ligadas a la aplicación de sus conocimientos

4.2. Resultados del aprendizaje

RA34 - Capability to develop and evaluate machine-learning techniques and to design big data learning systems

RA7 - Capacidad para desarrollar y evaluar técnicas de aprendizaje automático y diseñar sistemas de aprendizaje para datos masivos

RA72 - Capability to understand, design, develop and evaluate machine-learning, deep-learning and generative AI technologies for a wide range of application areas

5. Descripción de la asignatura y temario

5.1. Descripción de la asignatura

In this laboratory students will learn the experimental methodology to develop and apply Machine Learning (ML), Deep Learning (DL) and Artificial Intelligence (AI) methods, presented in the Predictive and Descriptive Learning course, to practical scenarios and case studies.

Through real case studies students will learn the major steps in the ML, DL and AI development cycle: from the relevance of Problem Definition and Exploratory Data Analysis to the aplication of solid experimental design principles for accurate and stable training of models and solid assessment and validation. This will include, feature selection and hyper-parameters optimization for ML, designing appropriate architectures and training strategies (transfer-learning, fine tuning, self-supervised, contrastive, zero-shot, few-shot, in-context,..) for DL and practicing with conditioning for Generative AI models (VAEs, VQ-VAEs, GANs, Flow Models, Diffusion models, Consistency models, ...). Emphasis will be given to ablation studies, interpretability and explainability of models as well as considering biases and ethical issues mainly for Generative AI applications.

Students will get practical skills using scientifically-oriented processing environments and libraries such as TensorFlow, Keras, Pytorch, Python scikit-learn, and resources from AI communities such as Hugging Face, Kaggle, Discord, AI coding assistants.

The lab will also provide introductory courses to ML and Multimodal AI services in cloud platforms: Google Cloud, AWS and Azure, where student will learn the for the lifecycle and deployment of applications.

By the end of the course, students should be able to:

Understand how to design and apply the most used ML, DL and Generative AI technologies to different real

scenarios.

Design a proper experimental methodology for accurately assessing and gaining knowledge from the use of each one of the different technologies, models and learning strategies.

Work with both scientifically-oriented processing environments and cloud platforms that can be used in a wide range of applications in science and industry, and understand how to use resources provided by AI communities.

Activities during the course, shown in next section, will gradually present contents in Lessons 1 to 4 along with several case studies, either defined by instructors or proposed by students, developed according the steps in Lesson 5.

5.2. Temario de la asignatura

1. Principles for developing Machine Learning (ML), Deep Learning (DL) and Artificial Intelligence (AI)
   - 1.1. Experimental methodology: from problem definition to model deployment and evaluation.
   - 1.2. Critical Analysis Evaluation: bias analysis, ablation studies, interpretability, explainability, ethical issues
2. Scientifically-oriented tools and environments
   - 2.1. Programing tools and AI coding assistants
   - 2.2. Statistical data analysis and processing
   - 2.3. Machine Learning
   - 2.4. Deep Learning
   - 2.5. AI communities and resources
3. Introduction to cloud platforms
   - 3.1. Principles of MLOps
   - 3.2. Hands-on ML and AI services under GCP, AWS, Azure
4. Generative AI
   - 4.1. Principles for developing Deep Generative models
   - 4.2. Applications based on Large Multimodal Models
5. Case studies (ML, DL, Generative AI)
   - 5.1. Problem Definition and Exploratory Data Analysis
   - 5.2. Experimental setup: databases, learning strategies, training, validation and testing protocols
   - 5.3. Machine Learning approach

5.4. Deep Learning approach

5.5. Generative AI application

5.6. Results discussion and Critical Analysis

6. Cronograma

6.1. Cronograma de la asignatura *

Sem	Actividad tipo 1	Actividad tipo 2	Tele-enseñanza	Actividades de evaluación
1		**Lesson 1** Duración: 02:00 LM: Actividad del tipo Lección Magistral **Lesson 2 (2.1)** Duración: 01:00 PL: Actividad del tipo Prácticas de Laboratorio		
2		**Lesson 2 (2.1)** Duración: 02:00 PL: Actividad del tipo Prácticas de Laboratorio **Lesson 5 (5.1)** Duración: 01:00 PL: Actividad del tipo Prácticas de Laboratorio		
3		**Lesson 5 (5.1)** Duración: 01:00 PL: Actividad del tipo Prácticas de Laboratorio **Lesson 2 (2.2)** Duración: 02:00 PL: Actividad del tipo Prácticas de Laboratorio		
4		**Lesson 5 (5.1)** Duración: 02:00 PL: Actividad del tipo Prácticas de Laboratorio **Lesson 2 (2.3)** Duración: 02:00 PL: Actividad del tipo Prácticas de Laboratorio		
5		**Lesson 2 (2.3)** Duración: 02:00 PL: Actividad del tipo Prácticas de Laboratorio **Lesson 5 (5.2)** Duración: 01:00 PL: Actividad del tipo Prácticas de Laboratorio		

6		**Case study activities: class review** Duración: 02:00 AC: Actividad del tipo Acciones Cooperativas **Lesson 5 (5.3)** Duración: 01:00 PL: Actividad del tipo Prácticas de Laboratorio		
7		**Lesson 5 (5.3)** Duración: 03:00 PL: Actividad del tipo Prácticas de Laboratorio		
8		**Lesson 2 (2.4)** Duración: 02:00 PL: Actividad del tipo Prácticas de Laboratorio		
9		**Lesson 2 (2.4)** Duración: 01:00 PL: Actividad del tipo Prácticas de Laboratorio **Lesson 3 (3.1)** Duración: 02:00 PL: Actividad del tipo Prácticas de Laboratorio		
10		**Lesson 2 (2.4)** Duración: 01:00 PL: Actividad del tipo Prácticas de Laboratorio **Lesson 3 (3.2)** Duración: 02:00 PL: Actividad del tipo Prácticas de Laboratorio		
11		**Lesson 3 (3.2)** Duración: 01:00 PL: Actividad del tipo Prácticas de Laboratorio **Lesson 4 (4.1)** Duración: 02:00 PL: Actividad del tipo Prácticas de Laboratorio		
12		**Lesson 4 (4.2)** Duración: 02:00 PL: Actividad del tipo Prácticas de Laboratorio **Lesson 3 (3.2)** Duración: 01:00 PL: Actividad del tipo Prácticas de Laboratorio		
13		**Lesson 5: reviewing case studies activities** Duración: 03:00 PL: Actividad del tipo Prácticas de Laboratorio		

14		**Lesson 5: presenting case studies results** Duración: 03:00 AC: Actividad del tipo Acciones Cooperativas		
15				
16				
17				**Evaluation: Developing Deep Learning models** TG: Técnica del tipo Trabajo en Grupo Evaluación Progresiva y Global No presencial Duración: 00:00 **Evaluation: Developing Machine Learning models** TI: Técnica del tipo Trabajo Individual Evaluación Progresiva y Global No presencial Duración: 00:00

Para el cálculo de los valores totales, se estima que por cada crédito ECTS el alumno dedicará dependiendo del plan de estudios, entre 26 y 27 horas de trabajo presencial y no presencial.

7. Actividades y criterios de evaluación

7.1. Actividades de evaluación de la asignatura

7.1.1. Evaluación (progresiva)

Sem.	Descripción	Modalidad	Tipo	Duración	Peso en la nota	Nota mínima	Competencias evaluadas
17	Evaluation: Developing Deep Learning models	TG: Técnica del tipo Trabajo en Grupo	No Presencial	00:00	50%	3.5 / 10	CB09 CT01 CB07 CB08 CT03 CB06 CE02 CT04 CE01 CT06 CE03 CT05 CB10
17	Evaluation: Developing Machine Learning models	TI: Técnica del tipo Trabajo Individual	No Presencial	00:00	50%	3.5 / 10	CB08 CB09 CT01 CB07 CT03 CB06 CE02 CT05 CB10

7.1.2. Prueba evaluación global

Sem	Descripción	Modalidad	Tipo	Duración	Peso en la nota	Nota mínima	Competencias evaluadas
17	Evaluation: Developing Deep Learning models	TG: Técnica del tipo Trabajo en Grupo	No Presencial	00:00	50%	3.5 / 10	CB09 CT01 CB07 CB08 CT03 CB06 CE02 CT04 CE01 CT06 CE03 CT05 CB10

17	Evaluation: Developing Machine Learning models	TI: Técnica del tipo Trabajo Individual	No Presencial	00:00	50%	3.5 / 10	CB08 CB09 CT01 CB07 CT03 CB06 CE02 CT05 CB10

7.1.3. Evaluación convocatoria extraordinaria

Descripción	Modalidad	Tipo	Duración	Peso en la nota	Nota mínima	Competencias evaluadas
Evaluation: Developing Machine Learning models	TI: Técnica del tipo Trabajo Individual	Presencial	00:00	50%	3.5 / 10	CT05 CB08 CT03 CB10 CB09 CE02 CT01 CB06 CB07
Evaluation: Developing Deep Learning models	TG: Técnica del tipo Trabajo en Grupo	Presencial	00:00	50%	3.5 / 10	CB10 CT04 CT05 CT06 CB08 CB09 CE02 CT01 CE01 CE03 CB06 CB07

7.2. Criterios de evaluación

Evaluation will assess if students have acquired all the competences of the subject. Thus, evaluation through extraordinary assessment will be carried out considering all the evaluation techniques used in ordinary evaluation (EX, ET, TG, etc.).

Progressive evaluation will be the preferred assessment method as it will be suited to the optimum learning process along the course. It will consist of:

- A Machine Learning Report describing the activities that demonstrate skills in developing Machine Learning models. The evaluation of this Report will represent 50% of final grade. For progressive evaluation, this report must be due by the 9th week. Several course assignments, which will be announced in Moodle, will be planned to review the students' progress through draft versions of their reports so we can give them feedback. We cloud also require students to prepare specific presentations to review their work.
- A Deep Learning Report must be prepared by the end of the course to demonstrate skills in developing Deep Learning models. The evaluation of this Deep Learning Report will represent 50% of final grade. Through several course assignments, announced in Moodle, we will review the students' progress while working on this Report. We cloud require students to attend to specific presentations to review their work.

Deep Learning activities must be developed in working teams, but each team member must individually clearly describe her/his specific activities in the Report.

Challenge-Based Learning

Optionally, students in the course could freely choose to follow a learning process based on undertaking a Challenge in Quantitative Finance.

The Challenge statement will be published at the beginning of the course, including a calendar that will be in accordance with the rest of the course.

Students may request the Challenge as a group or individually. In the latter case, the teachers will be in charge of forming the groups. In both scenarios the groups will be composed by two students, and the students must meet the requirements to be able to develop the group work.

The Challenge topics for the students' groups will be Quantitative Finance on different areas:

1. Quantification of patterns in leading market indicators.
2. Quantification of patterns in market value.

3. Quantification of seasonality in the main market indicators
4. Quantification of intra- and inter-day patterns, volatility, etc.

The development of the challenge will be divided into four phases:

1. Research: study of the challenge statement and research on possible solutions. The students will have to inform themselves and formulate questions that will allow them to understand the dimension of the challenge and to approach a possible solution.
2. Development of the challenge: students will develop in teams small activities leading to identify the most appropriate solution to the problem, all of them proposed by the teacher in view of the previous stages.
3. Verification and validation: the results obtained and the chosen solution will be contrasted in real environments.
4. Elaboration of the report and/or exhibition: the results will be shared through a working report and/or an exhibition, which may be done through a video.

The monitoring of the phases of the activity will be developed in tutorial sessions with the teachers designated for this purpose. The evaluation will be carried out in a coordinated way between the teachers and the participants in the teams. The teachers will carry out a continuous evaluation of the performance and the achievement of the objectives set during the development of the challenge for each student. Likewise, after completing the challenge, students will perform a self-evaluation and a cross evaluation. The weight of the exercise in the grade will be the same as that assigned to the group work.

Global or final evaluation will consist of:

- A Machine Learning Report describing the activities that demonstrate skills in developing Machine Learning models. The evaluation of this Report will represent 50% of final grade and it must be due by the final exam date, although students can submit draft versions before that date can they can receive feedback on their work.
- A Deep Learning Report must be prepared to demonstrate skills in developing Deep Learning models. The evaluation of this Deep Learning Report will represent 50% of final grade and it must be due by the by the final exam date.

Deep Learning activities must be developed in working teams, but each team member must individually clearly describe her/his specific activities in the Report.

For both Reports, students can submit draft versions before the final submission date so they can receive feedback

on their work. Students will be required to attend to specific final presentations to defend their work on both Machine Learning and Deep Learning Reports.

Evaluation through extraordinary assessment will require the same process as the one described before for Global or final evaluation.

8. Recursos didácticos

8.1. Recursos didácticos de la asignatura

Nombre	Tipo	Observaciones
Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems	Bibliografía	Géron, Aurélien. Hands-on machine learning with Scikit-Learn, Keras, and TensorFlow: Concepts, tools, and techniques to build intelligent systems. O'Reilly Media, 2nd Edition
Introduction to Statistical Learning	Bibliografía	James, Gareth, et al. An introduction to statistical learning. Second Edition (2021) https://hastie.su.domains/ISLR2/ISLRv2_website.pdf
Python for data analysis	Bibliografía	McKinney, Wes. Python for data analysis: Data wrangling with Pandas, NumPy, and IPython. " O'Reilly Media, Inc.", 2012.
scikit-learn Machine Learning in Python	Recursos web	https://scikit-learn.org/stable/

CRAN Task View: Machine Learning & Statistical Learning	Recursos web	https://cran.r-project.org/web/views/MachineLearning.html
Keras: the Python deep learning API	Recursos web	https://keras.io/ Keras is an open-source neural-network library written in Python
PyTorch Tutorials	Recursos web	https://pytorch.org/tutorials/
Deep learning with Python.	Bibliografía	F Chollet. Manning Publications Co., 2017
Andrej Karpathy blog About Hacker's guide to Neural Networks	Recursos web	https://karpathy.github.io/
MLLB at Moodle	Recursos web	https://moodle.upm.es/titulaciones/oficiales/course/view.php?id=892
Hugging Face AI Community	Recursos web	https://huggingface.co/

9. Otra información

9.1. Otra información sobre la asignatura

The increasing relevance of technological developments based on Artificial Intelligence makes this course an educational activity directed to contribute to Goal 4.4 in Sustainable Development Goals (SDGs) 2030 United Nations Agenda, empowering our students with relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship.

Through approaching practical scenarios in our Lab, students will develop relevant skills and in-depth knowledge on the impact of different Artificial Intelligence techniques on different fields as health, environmental monitoring, smart energy management, or finance. This will help them to become more aware of how technology can contribute to several SDGs goals: end poverty (Goal 1), promote well-being (Goal 2), and promote sustainable management of water, energy, economic growth and industrialization (Goals 5, 6, 7, and 8) as well as to reduce inequality among countries (Goal 10).
Also, due to the relevance of using machine learning and artificial intelligence to extract value from data in a broad range of economic sectors, the course will also contribute to SDG Goal 17 (Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development) in particular working on systemic issues on Data monitoring and accountability (17.18 and 17.19)